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OPTIMIZING THE TRACOMETER FOR USE IN DETECTING IMPAIRMENT

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OPTIMIZING THE TRACOMETER FOR USE IN DETECTING IMPAIRMENT

OPTIMISATION DU TRACOMÈTRE DANS LA DÉTECTION DE L'AFFAIBLISSEMENT DES FACULTÉS

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ABSTRACT

Previous experiments (Noy, 1986) had shovn that a test on a tracometer, compared to a test on a critical tracking task, is better able to detect subjects with blood alcohol concentrations of 800 mg/L, but that the former took longer to carry out. The present experiments were designed to compare test results obtained with original and revised versions of the tracometer. The revised versions used fever movements per test, and fever positions on the target display. Results showed that individual differences bewteen subjects were equivalent for the original and revised versions. The question remains whether they would be so if the subjects had ingested alcohol.

RÉSUMÉ

Des expériences antérieures (Noy, 1986) avaient démontré qu'une épreuve à l'aide du tracomètre était plus efficace pour la détection des sujets ayant une alcoolémie de 800 mg/L qu'une épreuve comportant une tâche compensatoire, mais qu'elle était plus longue à effectuer. Les expériences dont il est question ici ont été conçues dans le but de comparer les résultats obtenus avec les versions originales et modifiées du tracomètre. Pour les versions modifiées, chaque épreuve comprenait moins de mouvements et moins de positions dans l'affichage de la cible. Les résultats ont démontré que les écarts individuels étaient semblables pour les versions originales et modifiées. On se demande toutefois si les écarts demeureraient les mêmes si les sujets avaient consommé de l'alcool.

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OPTIMIZING THE TRACOMETER FOR USE IN DETECTING IMPAIRMENT

1.0 INTRODUCTION

Legislation which defines the offence of driving while under the influence of alcohol, assumes that behavioural impairment is related to the concentration of alcohol in the blood, and frames its provisions in terms of blood alcohol concentration rather than impairment as such. This is because blood alcohol concentration, compared to behavioural impairment, is both easier to specify and easier to measure. However, this avoids the real issue, for what is socially unacceptable is the impaired driver's behaviour and not his or her biochemical condition.

Despite the difficulties of measurement, attempts have, nevertheless, been made to detect states of impairment in persons convicted of driving while under the influence of alcohol. By incorporating a test into the ignition mechanism of a car, so that the car cannot be started unless the driver can first perform the task at some minimal level of competency, something may be done to prevent their repeating the offence.

One device designed with this purpose in mind is the critical tracking task, which is an unstable compensatory tracking task. However, while the critical tracking task succeeds in its objective to some degree, it also fails in some degree in that it passes as competent some drivers whose blood alcohol concentration is higher than the legal limit, and it fails as incompetent some whose concentration is below the legal limit.

We could argue, in view of our previous comments, that this result indicates the inappropriateness of using blood alcohol concentration as the criterion for competency, but while the law remains as it is the critical tracking task must be judged inadequate to the task of detecting criterial levels of blood alcohol.

One solution to the problem posed by the inadequacy of the critical tracking task is to use a better behavioural test of blood alcohol concentration. With this in mind (Noy, 1986) has compared the effectiveness of the critical tracking task with that of another performance test, the tracometer. He was successful in showing that the tracometer was better able to detect subjects with blood alcohol concentrations exceeding 800 mg/L.

The tracometer is a subject-paced pursuit tracking task. As such it requires a more complex target display than the simple error display used by the critical tracking task. It also requires, in its present form, a longer test period. These features mean that it is not so easily incorporated into the instrument panel of a car, and it would be less acceptable to a driver wishing to start the car and to get away.

The experiments described here were designed to test whether the form of the tracometer and the procedure for carrying out a test could be simplified. The performance of subjects using modified versions of the tracometer was compared with that using the original standard version. No tests were carried out at this point to see whether the simplified versions could equally well detect impairment due to alcohol.

2.0 THE TRACOMETER

The tracometer is a general purpose test of perceptual motor performance developed by the National Research Council of Canada (Buck, 1983). The subject pursues a target as it moves between five positions aligned linearly on the display. The target moves to the next position in the sequence only when the pursuit pointer is successfully aligned with the target, that is when it is held in position for 200 msec without loss of alignment. The task is therefore subject-paced, and the test sequence of 100 target movements lasts for a period dependent upon the subject's speed of response and movement.

Another feature of the task is that the pointer moves on the display in the direction opposite to that of the movement of the control wheel, that is there is control-display incompatibility.

Trained subjects can complete a test trial in about 140 seconds (Buck, et al., 1981). Untrained subjects take longer, and it requires about 16 training trials for performance to approach a plateau. This presents a problem in using the device for test purposes since training must be completed if one is to measure anything other than the effects of practice. However, this is a problem common to all perceptual motor tests.

3.0 MODIFICATIONS OF THE TASK

Because the target can take any one of five positions on the display the target sequence must contain multiples of twenty movements for all possible movements to be equally represented. It is important that they should be all equally represented because performance varies with directional probability (left versus right movement on the display) and with movement amplitude (distance travelled between positions), and unbalanced sequences produce biassed performance scores. The practice has been to use 100-movement sequences but sequences of 80, 60, 40 or 20 movements can conceivably be used to reduce time taken to complete a test. The question is whether this affects the test results.

Another possibility is to reduce the number of positions to a smaller number. In practical terms this is three. In this case target sequences would have to be multiples of six movements if all possible movements are to be equally represented, and this gives further opportunity to shorten the length of the trial. The question, again, is whether these changes to the task affect test results.

The tracking unit of the tracometer (the part that concerns the subject) consists of a metal box incorporating the control wheel, the target display and the pursuit pointer. It is too large to build into the instrument panel of a car and would require scaling down if it were to be used in that situation. From this point of view an oscilloscope, or a LED display, might be better than the metal box. Further possibility of miniaturization is offered by using a microprocessor in place of the obsolete electronic control unit currently used, although this would not affect the subject's view of the task.

Some of these modifications can be expected to affect absolute scores. Scaling down the display, and shortening the target movement sequence, would reduce total time taken because pointer travel would be reduced. However, in terms of the purpose of the test in the present context changing absolute time taken is not important. What is important is whether relative scores change.

Scores might change in relative terms in two ways. First, a modified task might be less sensitive to the effects of alcohol on performance, that is there might be an interactive effect between task design and blood alcohol concentration. Secondly, a modified task might be less sensitive to individual differences, and less able to distinguish one subject's performance from that of another. The first of these possibilities is the one that concerns us more, but it is easier and more straightforward to deal first with the second one. This is what we did in the experiments reported here.

We used an oscilloscope-microprocessor embodiment of the task, conceptually equivalent to the original task but differing from it in a number of ways. The targets were circles on the oscilloscope screen instead of illuminated ends of optic fibres, the target positions were arranged in line horizontally at 42.5-mm intervals instead of circumferentially at 41-mm intervals, and the pursuit element was a cross on the screen instead of a crosshair mounted on a perspex pointer. The pursuit elements in both cases were controlled by the same control wheel. The face of the oscilloscope was marked with a grid to indicate the approximate locations of the five positions, making it comparable to the tracking unit where the five positions were marked by the ends of the optic fibres.

4.0 EXPERIMENTAL DESIGN

Our hypothesis was that the various modified versions of the tracometer task differentiated equally between subjects and we predicted that scores on the various versions would be highly correlated.

Because our interest centred on the question of individual differences, and not on the effects of the task variables as such, we did not present the experimental conditions in a counterbalanced manner. Counterbalancing is a procedure followed in order to take account of practice effects, and it does this by confounding them with individual differences. For our purpose however, individual differences were of critical interest and we could not allow them to be modified by differential practice effects.

All subjects were, therefore, presented with the various versions of the task in the same order. This meant that differences between scores for different versions could be attributed to differences in amount of practice, but, as we were not interested in differences in absolute values, this was not important. The point was that for any given version all subjects had had the same preceding experience and practice of the same versions of the task.

5.0 EXPERIMENTAL PROCEDURE

Twenty-four young men, mostly students from local universities, were paid to act as subjects in the experiment. On the first day they attended the laboratory for a session lasting about one hour during which they performed eight trials on the original tracking unit followed by eight trials on an oscilloscope-based version of the tracometer. After each trial the subject was told his score in the form of total time taken for the trial.

The subjects returned the next day, each at the same time, to perform fifteen trials on the tracking unit followed by fifteen trials on the oscilloscope. For each device they performed three trials using 100-movement sequences, three using 80-movement, three using 60-movement, three using 40-movement, and three using 20-movement sequences. No knowledge of results was given until the completion of the whole session.

The subjects returned again about a month later for a third test session. On this occasion they each performed three refresher trials on the oscilloscope using 100-movement sequences, and then performed on three further modifications of the task, all presented on the oscilloscope. In the first version five target positions were used, and in the second and third only three. In the second version the three positions used corresponded to Positions 2, 3 and 4 of the five-position version so that the display width was 85 mm instead of 170 mm. In the third version Positions 1, 3 and 5 were used. These latter two conditions took account therefore of inter-target interval as well as the variation in the number of target positions.

For each version subjects performed three trials using 60-movement sequences, followed by three trials using either 40- or 42-movement sequences, and finally three trials using 20- or 24-movement sequences. Apart from the initial refresher trials, no knowledge of results was given until the completion of the whole session.

6.0 RESULTS

The tracometer provides measures of the speed and accuracy of motor performance, including reaction times, movement times, error rates and overshoot rates. These scores are dependent upon certain within-task variables, notably directional probability and movement amplitude. The same effects were found in the various modified versions of the tracometer used in this experiment and serve in part to demonstrate that modified tasks were versions of the same task.

Our main objective in the present experiment was to study variations in the performance score used by Noy, that is total time taken. We were in any case compelled to confine our attention to this score because unfamilarity with a new operating system led to the loss of certain of our data.

We carried out four analyses of the data. The first involved the three 100-movement trials on Day 2. Table 1 shows 23 subjects (data for one subject was not available) ranked in order of their scores (total time taken) on the first trial, followed by their rank orders for the other two 100-movement trials on the tracking unit and for the three 100-movement trials on the oscilloscope.

Table 2 shows the product-moment and rank-order correlations between these scores. Product-moment correlations ranged from 0.70 to 0.94 (with F values from 20.53 to 154.98), and rank-order correlations ranged from 0.51 to 0.81 (with t values from 3.36 to 5.34). The two versions of the task differentiated in the same way between the 23 subjects and appeared to do so more reliably as subjects were more practised.

The second analysis involved all trials on the tracking unit performed on Day 2. Table 3 shows 24 subjects ranked in order of their scores using sequences of 100-movements and less. Because of loss of data, ranks are based on means of the set of three trials in each case. Table 4 shows the correlations between these mean scores. Product-moment correlations ranged from 0.82 to 0.97 with F values from 45.66 to 384.59, and rank-order correlations ranged from 0.71 to 0.86 with t values from 4.73 to 5.81. All correlations were positive and highly significant but they tended to be lower for the shorter sequences.

The third analysis involved the corresponding trials performed on the oscilloscope on Day 2 and Tables 5 and 6 show the results. Product-moment correlations ranged from 0.88 to 0.96 with F values from 76.96 to 287.67, and rank-order correlations ranged from 0.64 to 0.84 with t values from 4.32 to 5.77. These also showed that correlations tended to be lower for the shorter sequences.

The fourth analysis involved all trials performed on Day 3 (except the refresher trials). Table 7 shows the rank order for 20 subjects (data for four subjects were not available) and Table 8 the correlations. Product-moment correlations ranged from 0.56 to 0.95 with F values from 8.02 to 156.25, and rank-order correlations ranged from 0.48 to 0.81 with t values from 2.89 to 4.96. The results showed the shorter-sequence effect. They also showed that the narrow-amplitude three-position task correlated slightly more highly with the five-position task than did the wide-amplitude three-position task.

7.0 DISCUSSION

The results of the experiment allow us to make a number of conclusions. First, embodying the task in an oscilloscope in place of the original metal box device did not materially affect the data. If anything, the results from the oscilloscope were more reliable, although

this could be reasonably attributed to the fact that the subjects were more practised when they used it. Other embodiments of the tasks, provided they used five target positions and 100-movement sequences, may be equally reliable and there is therefore no basic reason for rejecting the task because of problems of building it into the instrument panel.

Secondly, the movement sequence could be shortened. Scores for 80- and 60-movement sequences correlate highly with those for the standard 100-movement sequence. Beyond that point correlations, although high, fall off, and a 60-movement sequence is probably as low as one would want to go. Shorter sequences, apart from being intrinsically different to longer sequences, also have the disadvantage of being more susceptible to the effects of data loss in the sense that one or two data lost in a 100-movement sequence involve less error than the same number lost in a 20-movement sequence. However, the differences in the correlations were somewhat less marked when the oscilloscope was used.

Thirdly, the number of target positions can be reduced from five to three, although if this is done it is marginally better to use the narrow-amplitude display than the wide-amplitude display. This gives an added advantage because the narrow display occupies less room and a given number of movements requires less time.

The narrow-amplitude three-position task using a sequence of 60-movements required on average 67 seconds compared to 129 seconds required by the standard task.

We may conclude that the results of the present series of experiments give sufficient reason for proceeding to the second question, which is whether any or all of the modifications tested here are as successful as the standard version of the tracometer in differentiating blood alcohol levels.

8.0 REFERENCES

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Table 1
Rank orders of 23 subjects performing three 100-movement trials.

Subject	Tracking unit trials			Oscilloscope trials		
	1	2	3	1	2	3
A	1	5	1	5	7	12
B	2	10	5	7	4	4
C	3	11	6	4	3	2
D	4	1	2	1	1	1
E	5	4	4	13	12	10
F	6	9	13	10	2	5
G	7.5	3	3	9	5	3
H	7.5	6	7	8	9	6
I	9	2	9	6	8	10
J	10	16.5	8	12	11	7
K	11	13	14	11	13.5	13
L	12.5	16.5	12	14	10	14
M	12.5	21	17	17	17	18
N	14	7	10	3	6	10
O						
P	16	12	16	19	16	15
Q	17	20	18	18	21	21
R	18	15	20	20	20	19
S	19	14	15	16	15	16
T	20	23	23	23	23	23
U	21	22	21	15	18	17
V	22	18	19	21	19	20
W	23	19	22	22	22	22

Table 2
Correlations between scores on 100-movement trials for 23 subjects.

Trials		Tracking unit trials			Oscilloscope trials		
		1	2	3	1	2	3
Tracking unit							
1	p	-	70	82	80	80	81
	r		51	74	55	67	65
2	p		-	85	79	81	78
	r			67	57	57	56
3	p			-	86	88	86
	r				63	70	71
Oscilloscope							
1	p				-	91	93
	r					69	71
2	p					-	94
	r						81

Note. p - Pearson's product-moment correlation
r - Kendall's rank order correlation
Decimal points have been omitted

Table 3
Rank orders of 24 subjects performing the tracking-unit task, based on mean scores for sets of three trials.

Subject	Number of movements per trial				
	100	80	60	40	20
A	2	3	3.5	4.5	4.5
B	5	9	3.5	9	16.5
C	3	5	9	4.5	4.5
D	1	1	1	1	1
E	10	4	7	7.5	7.5
F	8	12	10.5	13	7.5
G	4	2	6	2.5	7.5
H	7	6.5	8	6	11
I	6	8	5	10	3
J	12	13	15.5	12	11
K	13	14	12	14	11
L	14	11	13	11	15
M	18	18	19	18	16.5
N	9	10	10.5	7.5	7.5
O	11	6.5	2	2.5	2
P	16	16	15.5	15	14
Q	21	21	22	21	18.5
R	19	24	23	22	21.5
S	17	16	14	16	13
T	24	22	24	23	24
U	20	19	17	24	20
V	22	20	20	19	23
W	23	23	21	20	21.5
X	15	16	18	17	18.5

Table 4
Correlations between tracking unit scores for 24 subjects, based on mean scores for sets of three trials.

		Number of movements				
		100	80	60	40	20
100	p	-	95	95	88	88
	r		81	75	75	72
80	p		-	97	87	88
	r			80	86	71
60	p			-	82	88
	r				79	75
40	p				-	85
	r					72

Note. p - Pearson's product-moment correlation
r - Kendall's rank-order correlation
Decimal points have been omitted

Table 5
Rank orders of 24 subjects performing the oscilloscope task, based on mean scores for sets of three trials.

Subject	Number of movements per trial				
	100	80	60	40	20
A	9	6	5	6	3
B	3	8	5	12	14
C	2	4	8	3	3
D	1	2	2	1	1
E	13	5	2	6	6
F	4	13	13	12	6
G	4	1	2	2	5
H	8	8	5	9	9
I	7	7	9	4	6
J	11	11	16	11	10
K	12	12	12	10	14
L	14	14	10	15	10
M	19	18	19	16	17
N	6	10	11	6	14
O	10	3	1	5	2
P	17	16	17	16	10
Q	22	21	21	23	19
R	20	23	22	22	23
S	15	19	15	18	13
T	24	22	23	24	24
U	18	15	14	12	19
V	21	20	20	20	19
W	23	23	24	21	22
X	16	16	18	18	18

Table 6
Correlations between oscilloscope scores for 24 subjects, based on mean scores for sets of three trials.

		Number of movements				
		100	80	60	40	20
100	p	-	92	91	93	89
	r		69	64	70	65
80	p		-	96	96	90
	r			84	86	75
60	p			-	94	88
	r				74	71
40	p				-	89
	r					73

Note. p - Pearson's product-moment correlation
r - Kendall's rank-order correlation
Decimal points have been omitted

Table 7
Rank orders of 20 subjects performing five- and three-position tasks, based on mean scores for sets of three trials.

Subject	five-position (narrow amplitude)			three-position (narrow amplitude)			three-position (wide amplitude)		
	Number of movements per trial								
	60	40	20	60	42	24	60	42	24
A	2	6	6	7.5	5	6	4	2	9
B	6	7	12	10	3	5	5	7	11
C	5	2.5	1.5	2	4	3	8	15	8
E	13	12	14	6	7	12	11	5	5
F	8	11	5	12	11	13	7	8	6.5
G	1	1	1.5	1	1	1	1	1	1
H	4	8	7.5	7.5	8	7	10	9	12
I	9	2.5	4	4	6	4	3	4	4
J	12	9	11	9	9	9	6	6	14
K	11	13	16	15	16	16	15	14	16
M	10	10	13	14	14	10	9	11	10
N	7	5	7.5	5	13	14	14	12	3
O	3	4	3	3	2	2	2	3	2
P	15	16	17	16	17	15	16	16	13
Q	17	19	9	19	19	19	20	20	20
R	19	20	20	17	18	20	18	18	19
S	14	14	10	13	12	11	13	13	15
T	20	18	19	20	20	18	17	17	18
U	16	15	15	11	10	8	12	10	6.5
W	18	17	18	18	15	17	19	19	17

Table 8
Correlations between five- and three-position tasks for 20 subjects, based on mean scores for sets of three trials.

Task			five-position (narrow amplitude)			three-position (narrow amplitude)			three-position (wide amplitude)		
			Number of movements per trial								
			60	40	20	60	42	24	60	42	24
5n	60	p	-	95	84	92	85	89	87	81	87
		r		75	63	65	65	62	63	55	52
	40	p		-	85	94	88	92	90	80	90
		r			72	78	68	75	73	59	64
	20	p			-	79	76	78	70	56	71
		r				67	58	61	60	48	53
3n	60	p				-	94	92	92	86	91
		r					79	69	66	66	71
	42	p					-	91	90	80	83
		r						80	75	71	59
	24	p						-	94	84	92
		r							78	65	60
3v	60	p							-	95	89
		r								81	60
	42	p								-	85
		r									62

Note. p - Pearson's product-moment correlation
r - Kendall's rank-order correlation
Decimal points have been omitted

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NOTES

13

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14 Tracometer, alcohol impairment

SUMMARY/SOMMAIRE

15 Describes experiments aimed at optimizing the design of the tracometer with a view to using it as a vehicle-installed impairment detection device.

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